WIICA

Workload ISA-Independent Characterization for Applications

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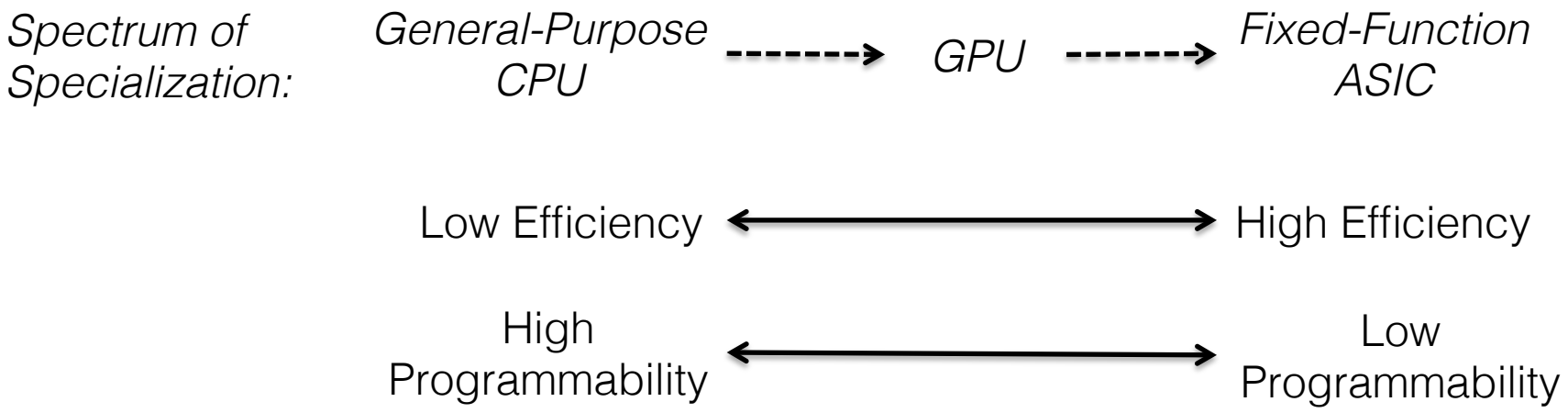
Specialized architectures are decoupled from legacy ISAs.



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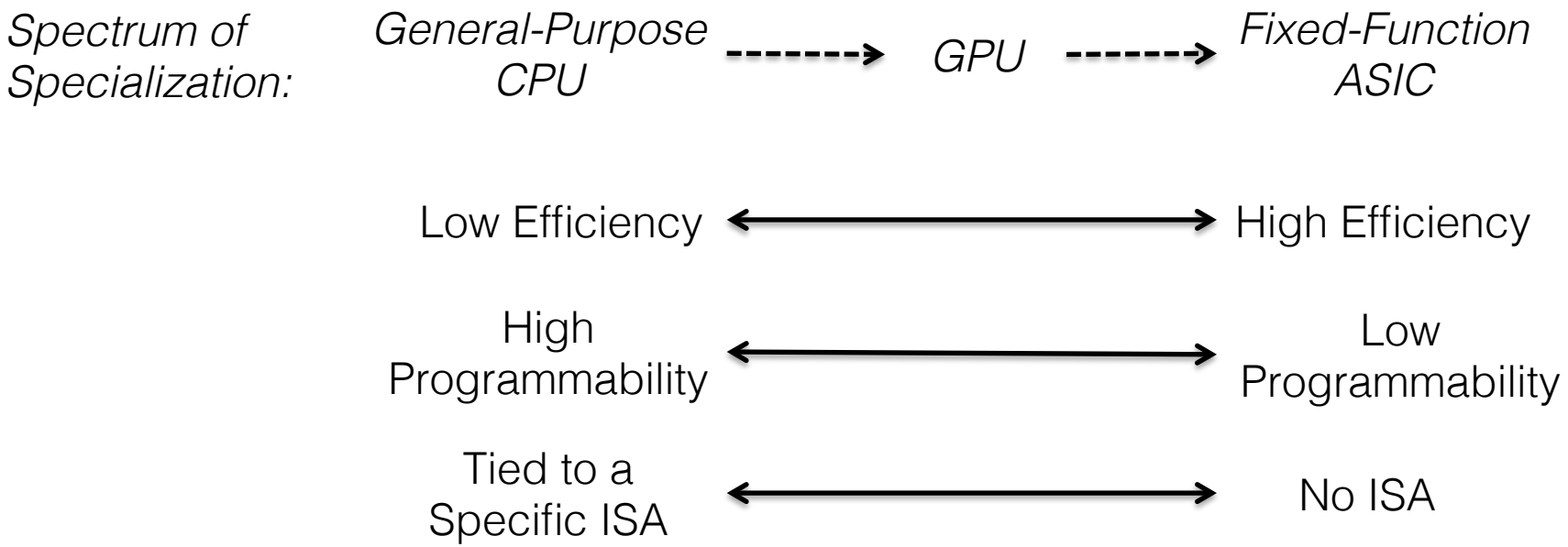

Performance-Counter Based Workload Characterization

- Metrics
  - IPC
  - Cache miss rates
  - Branch mis-prediction rates
  - …
- Microarchitecture-dependent
  - What if there is a bigger cache/a better branch predictor?
  - Not program intrinsic characteristics

ISA impacts program behaviors.

Stack Overhead

- Limited Registers
- Additional Load/Store

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Complex Operations

- Memory Operands
- Vector Operations

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Calling Conventions

WIICA Summary

Goal:

- An analysis tool to characterize workloads ISA-independent characteristics for specialized architectures

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- Categorize characteristics into compute, memory, and control

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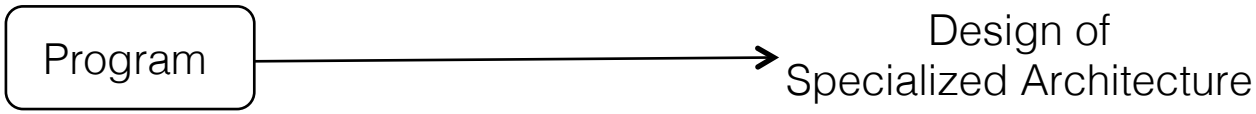
Takeaways:

- ISA-dependent characterization is misleading for specialization.
- ISA-independent characterization allows designers to quickly identify opportunities for specialization.

Tool Overview



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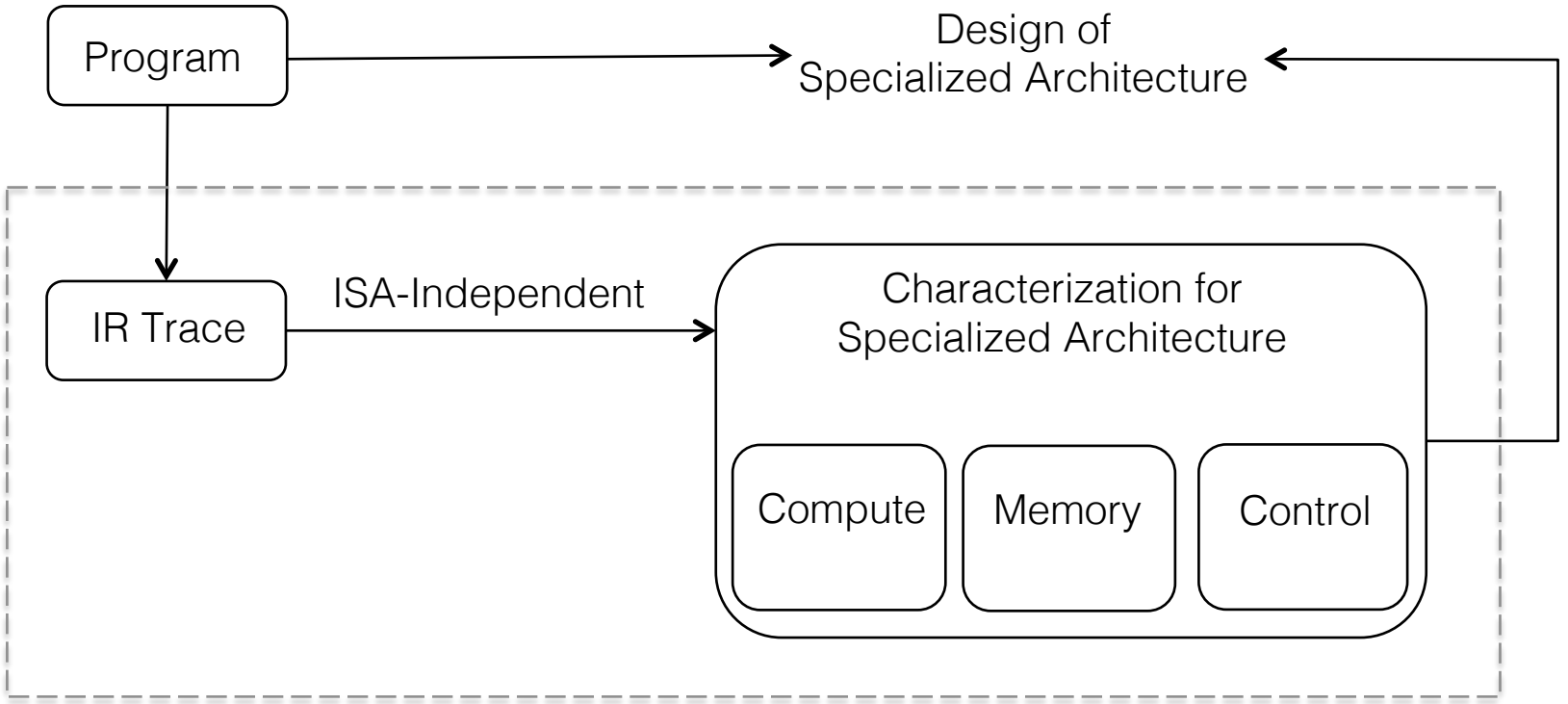

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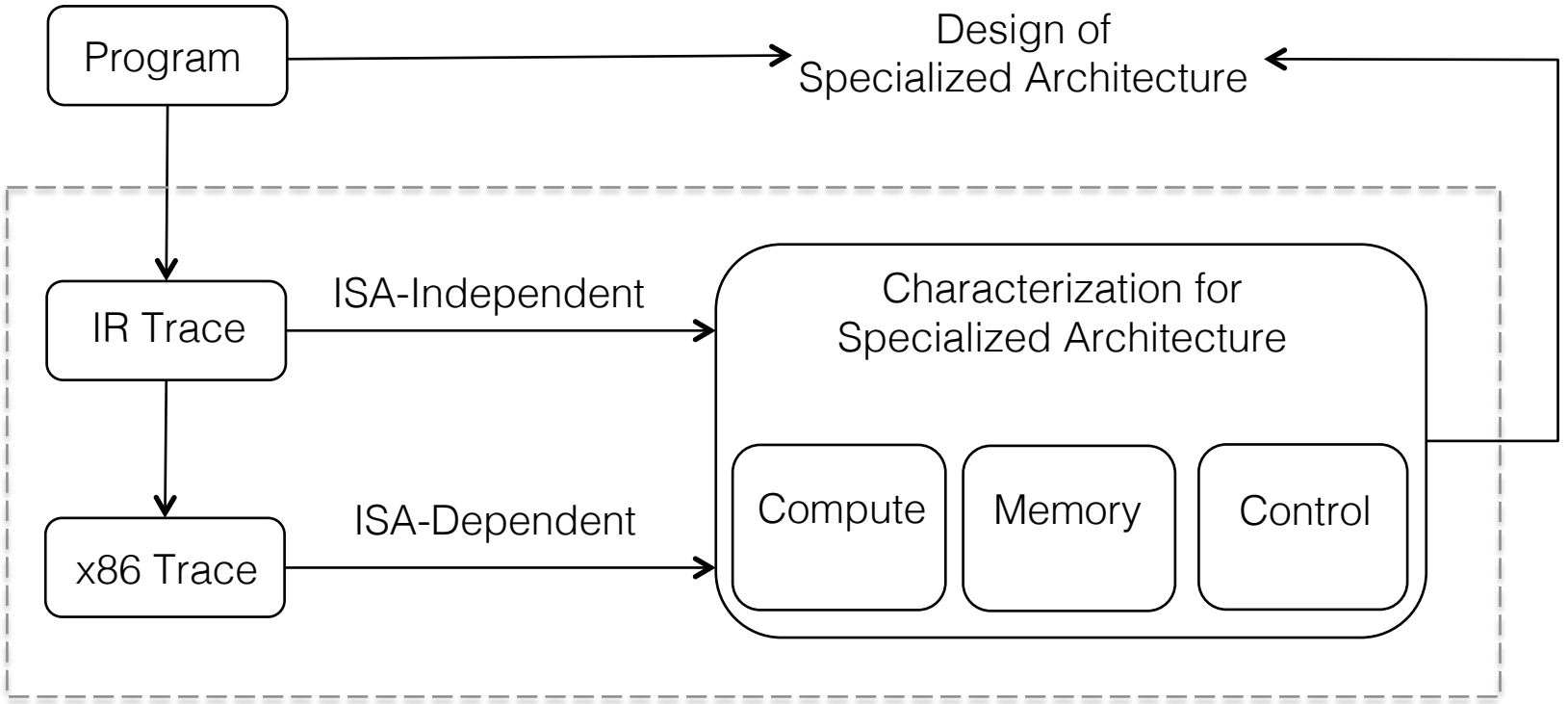
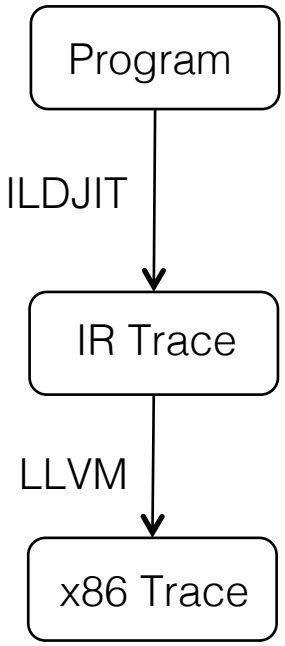


Program Representations



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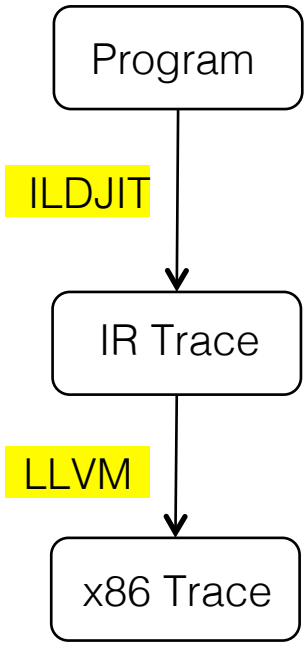
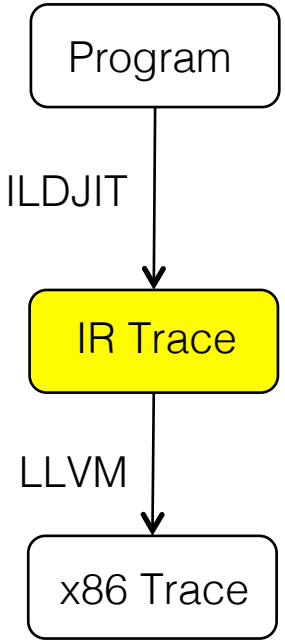


ILDJIT

- A modular compilation framework
- Performs machine-independent classical optimizations at the IR level
- Uses LLVM's back end to
  - Do machine-dependent optimizations
  - Generate machine code

Campanoni, et al., A Highly Flexible, Parallel Virtual Machine: Design and Experience of ILDJIT, Software Practice Experience, 2010

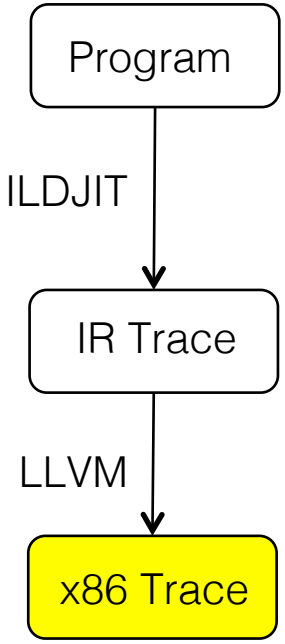
Program Representations



ILDJIT IR

- High-level IR
- Machine-, ISA-, and system-library-independent
- Features:
  - 80 instructions
  - Unlimited registers
  - Only loads/stores access memory
  - No vector operations
  - Parameters are passed by variables

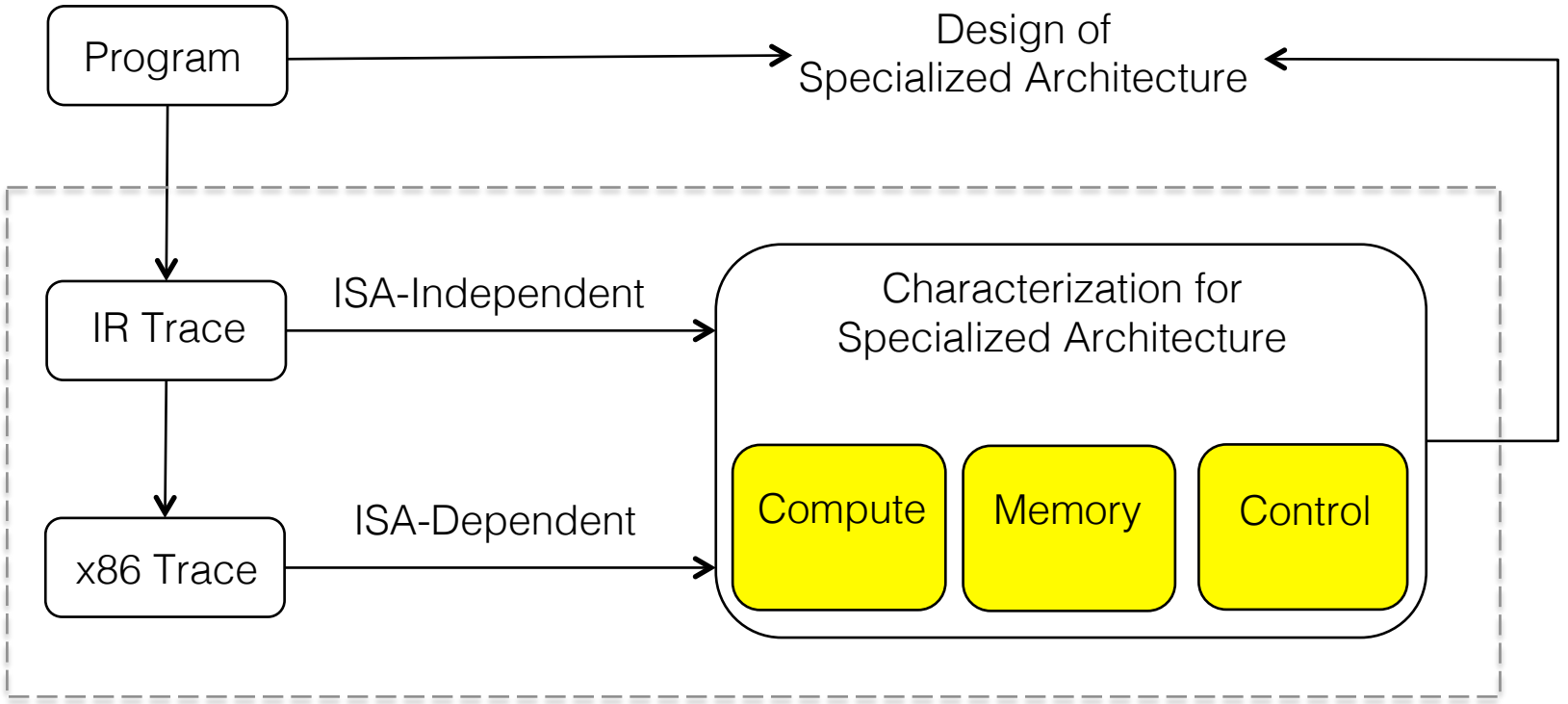
Program Representations



x86 Trace

- Used for ISA-dependent analysis
- Semantically equivalent to the IR code
- Collected with Pin instrumentation

Tool Overview



ISA-Independent Workload Characteristics

Compute

- Opcode Diversity
- Static Instructions (I-MEM)

Memory

- Memory Footprint (D-MEM)
- Memory Entropy
- Locality Score

Control

- Branch Instruction Counts
- Branch Entropy

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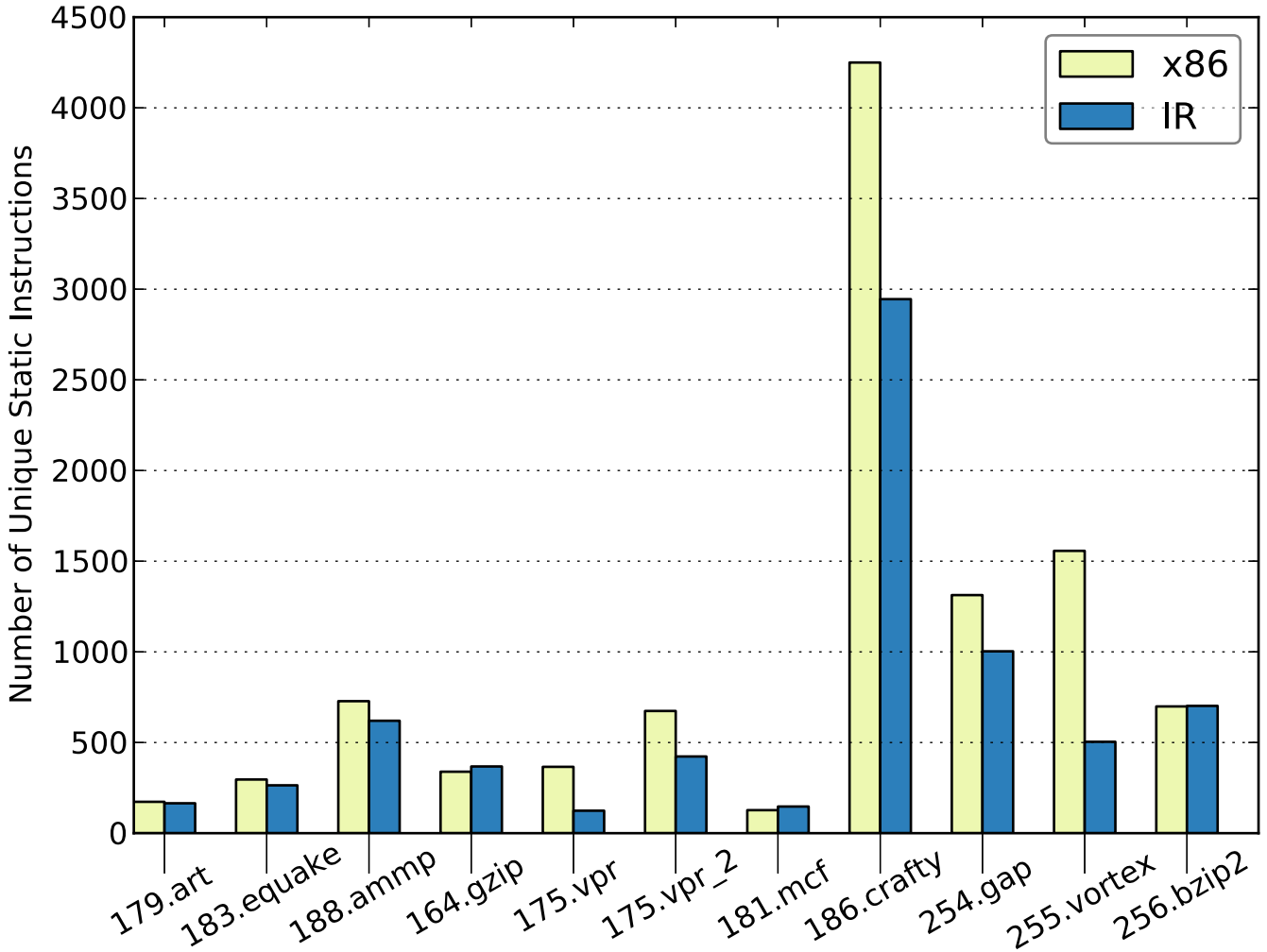
Compute::Static Instructions



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Memory::Entropy

Entropy: a measure of the randomness

$$Entropy = -\sum_{i=1}^{N} p(x_i) * \log_2 p(x_i)$$

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$$Entropy = -\sum_{i=1}^{N} p(x_i) * \log_2 p(x_i)$$

Case 1:

X is always a constant.

$$p(X) = 1$$
$$\log_2 p(X) = 0$$
$$Entropy = 0$$

Case 2:

N possible outcomes of X occur equally.

$$p(X) = \frac{1}{N}$$
$$\log_2 p(X) = \log_2 N^{-1}$$
$$Entropy = -N * \frac{1}{N} * \log_2 N^{-1}$$
$$Entropy = \log_2 N$$

Memory::Global Address Entropy

Temporal Locality

Address Stream A (less temporal locality)	Address Stream B (more temporal locality)
0 0 0 0	0 0 1 1
0 0 0 1	0 0 1 1
0 0 1 0	0 0 1 1
0 0 1 1	0 0 1 1
Entropy = **2**	Entropy = 0

Yen, Draper, and Hill. Notary: Hardware Techniques to Enhance Signatures. MICRO 08

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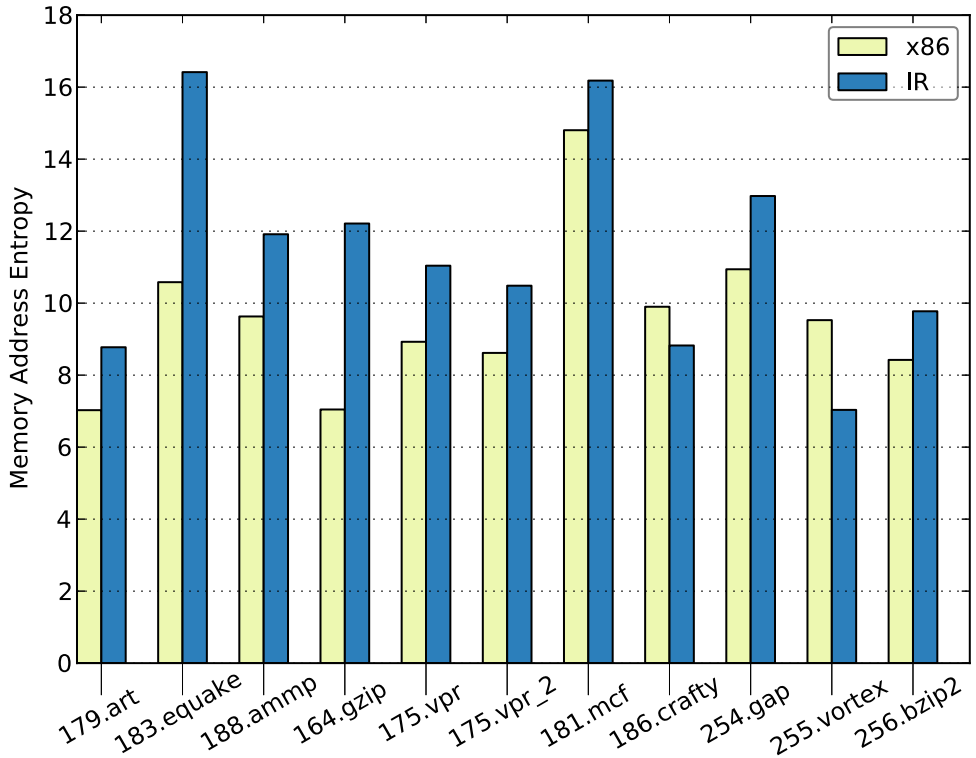

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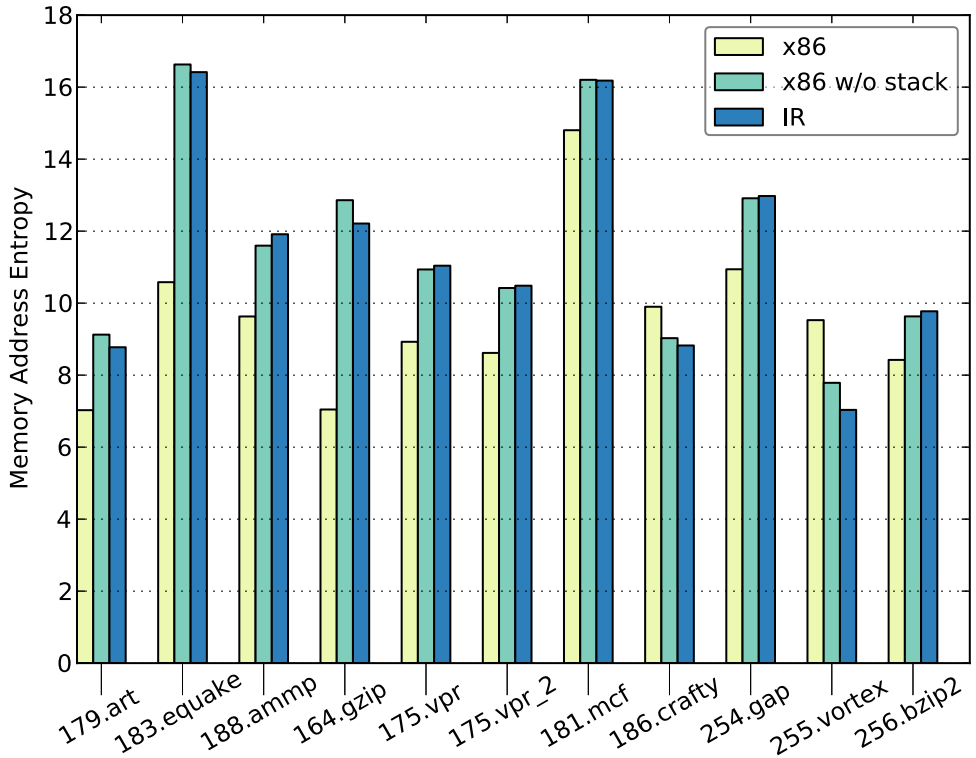

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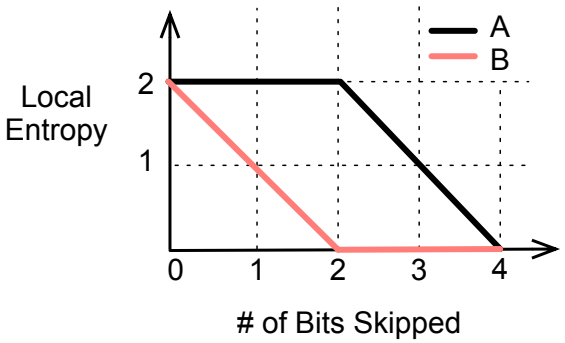
Memory::Local Address Entropy

Spatial Locality

Address Stream A (less spatial locality)	Address Stream B (more spatial locality)
0 0 0 0	0 0 0 0
0 1 0 0	0 0 0 1
1 0 0 0	0 0 1 0
1 1 0 0	0 0 1 1



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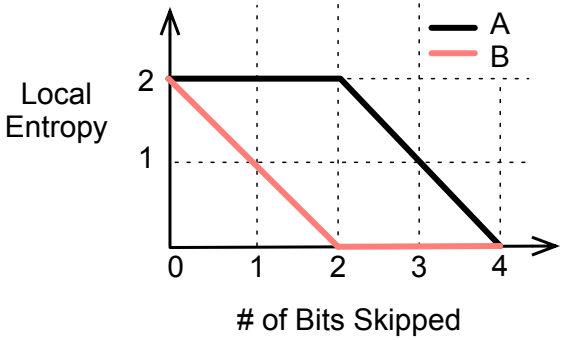

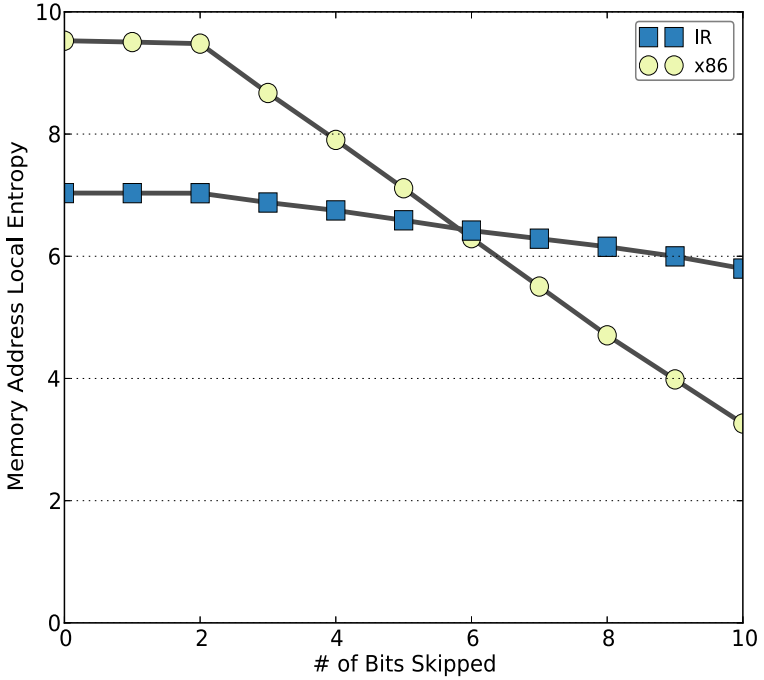

Memory::Spatial Locality Score

Address Stream A (less spatial locality)	Address Stream B (more spatial locality)
0x0000	0x0000
0x0004	0x0001
0x0008	0x0002
0x000C	0x0003

$$L = \frac{P(stride = 4)}{stride = 4} = \frac{1}{4}$$

$$L = \frac{P(stride = 1)}{stride = 1} = 1$$

$$L_{spatial} = \sum_{stride=1}^{stride<\infty} \frac{P(stride)}{stride}$$

Weinberg, et all, Quantifying Locality in the memory access patterns of HPC applications, In SC, 2005

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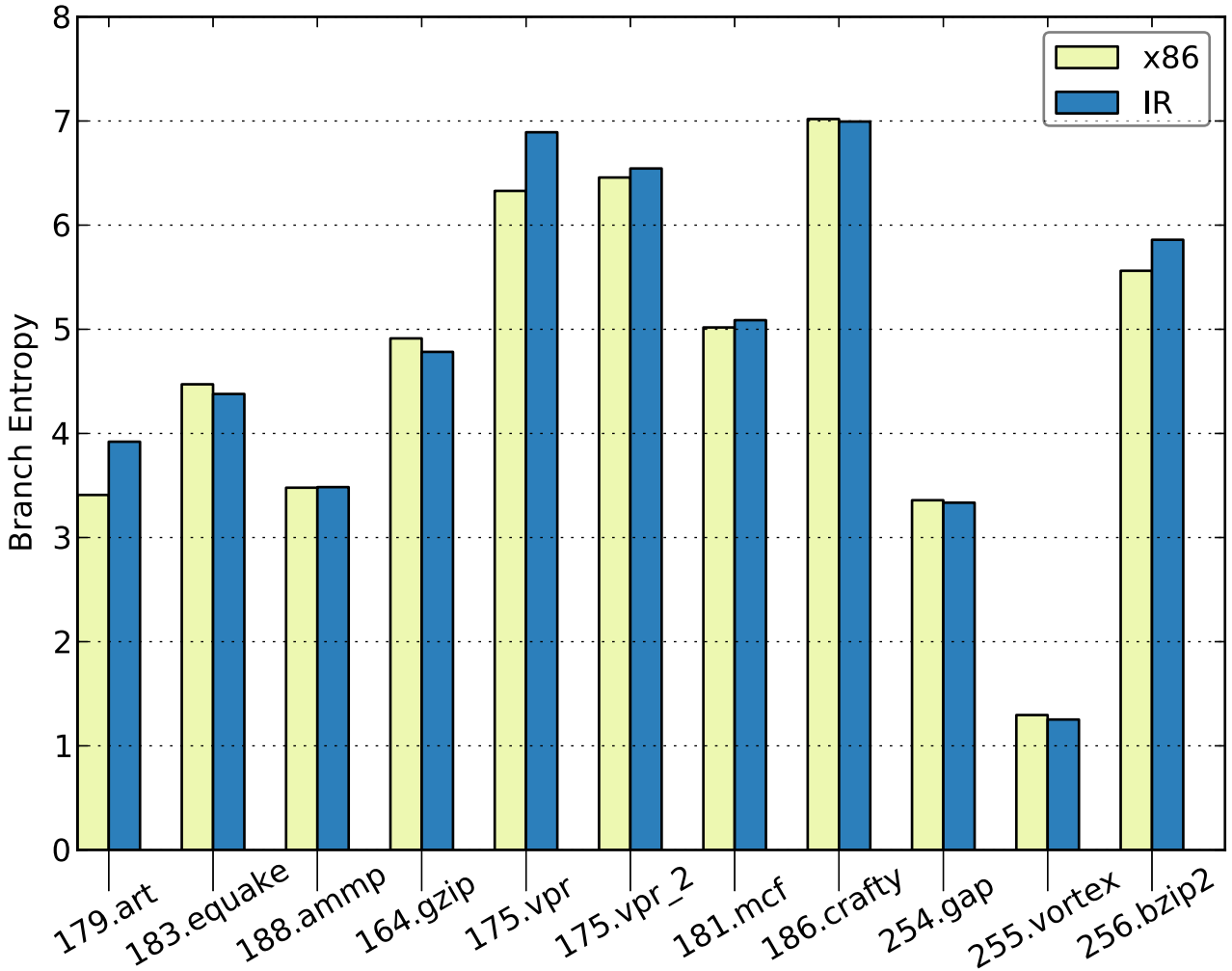
Yokota, et all, Introducing Entropies for Representing Program Behavior and Branch Predictor Performance, 07

Control::Branch Entropy



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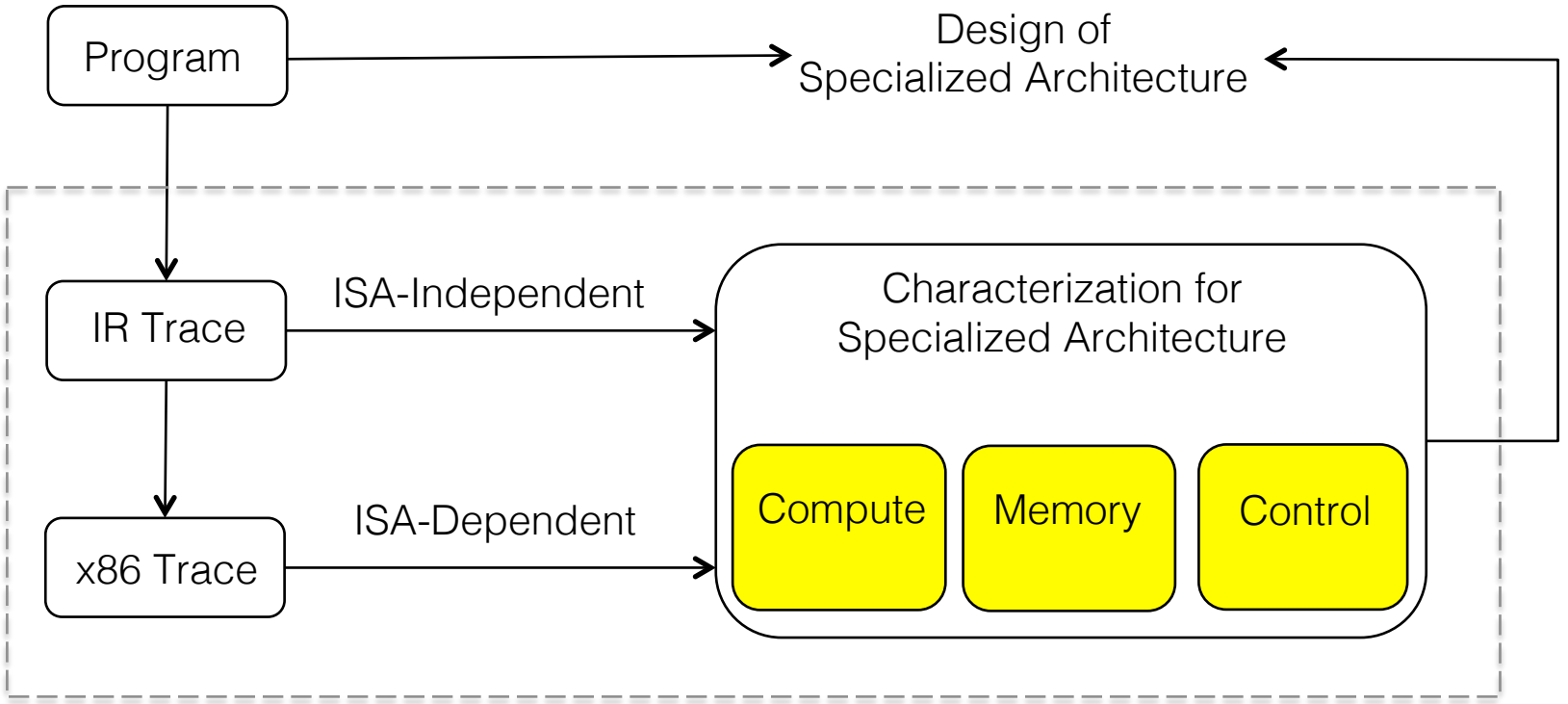

Publications

- Implications of the Power Wall: Dim Cores and Reconfigurable Logic
  - Wang and Skadron, IEEE Micro, 2013

- ISA-Independent Workload Characterization and its Implications for Specialized Architectures
  - Shao and Brooks, ISPASS, 2013